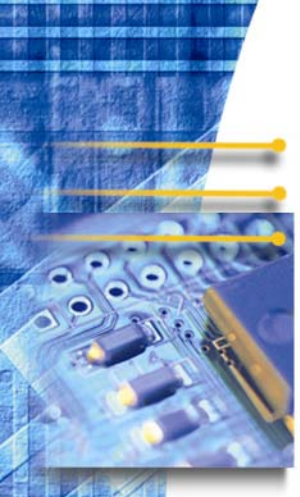

Lead-Free Electronics: They're Here to Stay

Chris Jorgensen

IPC Technical Project Manager

Lead-Free Electronics: Positioning Massachusetts Companies as Industry Leaders

North Andover, Mass.

April 13, 2000

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Overview

- 10,000 tons of SnPb solder used annually
- Pb indicated as a hazardous element
  - Legislative action has pushed for its removal
    - Plumbing solders and tin cans
    - Household paints
    - Bullets
  - US electronics industry currently exempted from legislation
- Industry lulled to sleep…….

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Overview

WAKE UP CALL!!!!

- European legislation
- Stepped-up efforts by Japanese OEMs
- NIST - US industry stands to lose $420 billion in three-year period following 2002 unless it has a competitive edge
  (NIST ATP Web site)
- Now what????

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Overview

◆ IPC Board of Directors Position Statement

The US electronic interconnection industry, represented by the IPC, uses less than 2% of the world's annual lead consumption. Furthermore, all available scientific evidence and US government reports indicate that the lead used in US printed wiring board (PWB) manufacturing and electronic assembly produces no significant environmental or health hazards.

Nonetheless, in the opinion of IPC, the pressure to eliminate lead in electronic interconnections will continue in the future from both the legislative and competitive sides. IPC encourages and supports research and development of lead-free materials and technologies. These new technologies should provide product integrity, performance and reliability equivalent to lead-containing products without introducing new environmental risks or health hazards. IPC prefers global rather than regional solutions to this issue, and is encouraging a coordinated approach to the voluntary reduction or elimination of lead by the electronic interconnection industry.

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Worldwide Activities

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Political Activities

- **Japan**
  - **MITI take-back legislation 1997**
  - **Japanese Home Electronic Recycling Law**
    - Revised in 1998
    - Household appliance recycling in full force by April 2001
- **Sweden**
  - **Recommends lead phase-out by 2020**
- **Denmark**
  - **Prohibits import, sale and production of products containing metallic lead**

Political Activities

- **European Commission (EC) Waste Electrical and Electronic Environment (WEEE) Directive**
  - **Calls for lead ban in most electronics by 2004**
  - **Delegate General (DG)-Environment: *Industry is the problem and the solution***
  - **Fourth draft stalled due to changes in European Commission (EC)**
  - **Fourth draft scheduled for availability late April 2000**

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Political Activities

- **WEEE Directive Exemptions**
  - **Lead as an element in some alloys**
    - Steel - Containing up to 0.3% lead by weight
    - Aluminum - Containing up 0.4% by weight
    - Copper - Containing up to 4% lead by
  - **Lead in electronic parts**

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Political Activities

- **US**
  - Reid Bill - 1991
  - Lead Exposure Reduction Act - 1993
  - EPA proposed reporting requirements for lead usage limits from 25,000 lbs. to 10 lbs. - 1999
    - IPC opposes this proposal
    - Could prove very costly to smaller companies
    - Reconsidering small business impact
    - Staying focused on these activities

Political Activities

- **US States**
  - California
    - Proposition 65 - Safe Drinking Water and Toxic Enforcement Act of 1986
  - Connecticut
    - Department of Environmental Protection (DEP) plans to issue general permit for recycling electronics this year
  - South Carolina
    - State legislature evaluated a bill to establish a statewide electronic equipment recycling program.

Marketing/Competitive Pressures

- **Japan**
  - **Hitachi**
    - Lead usage in 1999 50% of that of 1997
    - All products lead free by 2001
    - Investing 1.2 billion Yen ($11.2 million) to expand production of lead-free solder
  - **Matsushita (Panasonic)**
    - Lead solder to be removed in 2000 from consumer electronics
    - All consumer electronics to be lead free by 2001
    - Will begin marketing products in US
  - **Toshiba**
    - Lead removed from all cell phones by 2002

Marketing/Competitive Pressures

- **Japan**
  - **Sony**
    - Lead usage in 1999 50% of that of 1996
    - Lead removed from all products except high-density packaging by 2001
    - Told its 500 suppliers to provide lead-free products
  - **NEC**
    - Lead usage by 2002 50% of that used in 1997
    - Currently using lead-free semiconductors
    - Began shipping lead-free product in January
    - Labeling lead-free from lead bearing products

Marketing/Competitive Pressures

- **US**
  - **Monitoring Japanese and European activities**
  - **Researching alternatives**
  - **Prefer product-by-product switch rather than overall requirement**
  - **Don’t want marketing to drive legislation**

Organizational Activities

- **IPC**
  - **www.leadfree.org**
    - Over 4000 visitors since August 1999
    - Lead Free Grapevine
    - Technical papers and articles
    - Host to IPC Roadmap for Lead-Free Electronics Assemblies
      - 2nd and 3rd drafts downloaded over 2000 times
  - **Leadfree@ipc.org**
    - E-mail forum for peer interaction
    - 500+ subscribers
    - Announcements for future roadmap meetings

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Organizational Activities

- **IPC**
  - **International Summit on Lead-Free Electronics Assemblies**
    - 500+ attendees
    - 35 presentations over five sessions
    - Initial roadmap development
    - Proceedings include updated presentations
  - **APEX 2000**
    - Technical forums, conference and roadmap work

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Organizational Activities

- EIA
  - Supports further research that could lead to minimizing lead use in the electronics industry, including the funding of a university-affiliated research program
- NIST - ATP
  - Lucent EC&S project for drop-in replacement - 1999
    - On target for 2001 completion

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Organizational Activities

- **NCMS**
  - **Lead-Free Solder Project - 1997**
    - Collaborative effort of OEMs, academia and laboratories
    - Tested 27 candidate alloys
    - Found no drop-in replacement, but resulted in good data
  - **High-Temperature Solder Project**
- **NEMI**
  - **North America needs to prepare to deliver lead-free products by 2001, with an “eye” for total lead elimination for 2004.**
  - **Proposed replacement alloys**

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Organizational Activities

- International Tin Research Institute (ITRI) - SOLDERTEC
  - Standardize lead-free materials
  - Collaborative research efforts
  - Over 10 years of lead-free research
  - Sponsors include alloy suppliers and OEMs
- IDEALS Project
  - Conducted by European companies
  - Production-ready processes for lead-free electronics
  - Reliability of final assemblies

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Organizational Activities

- **Japan Institute for Electronic Packaging (JIEP)**

First adoption of lead-free solders in mass produced goods	1999
Adoption of lead-free components	2000
Adoption of lead-free solders in wave soldering	2000
Expanded use of lead-free components	2001
Expanded use of lead-free solders in new products	2001
General use of lead-free solders in new products	2002
Full use of lead-free solders in all new products	2003
Lead-containing solder used only exceptionally	2005
Complete elimination of lead from electronic products	2007

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IPC Roadmap Findings

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Lead-Free Solder Selection

- **SnAgCu**
  - **Appears to be most popular candidate - with or without the addition of a 4th element**
  - **Chosen as benchmark for testing - SnPb is the baseline**
  - **Concerns**
    - Higher processing temperatures
    - Higher temperatures leads to more energy used - added cost
    - Compatibility with some lead bearing finishes
    - Toxicity of Ag

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Lead-Free Solder Selection

- **SnCu**
  - **Low-cost alternative for wave soldering**
  - **Compatible with most lead bearing finishes**
  - **Concerns**
    - Higher processing temperatures than most SnAgCu alloys
- **SnAgBi**
  - **Candidate for SMT applications**
  - **NCMS study showed better thermal cycle reliability for certain SMT than SnAgCu**
  - **Concerns**
    - Toxicity of Bi and Ag
    - Fillet lifting

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Lead-Free Solder Selection

- **SnZn**
  - **Low melting temperature**
  - **Long-term data needed**
  - **Concerns**
    - Zn oxidation
    - Long-term corrosion of solder joint
    - Requires special flux chemistries
    - Wetting characteristics not as good as SnAgCu

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Lead-Free Solder Selection

- **SnAg**
  - **Long history of usage**
  - **Extensive data - attractive to most companies**
  - **Concerns**
    - Higher melting temperatures than SnAgCu
    - Toxicity of Ag

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Lead-Free Solder Selection

- **Alloys by area of industry used**

ALLOYS USED	MELTING RANGE (°C)	INDUSTRY SERVED	COMPANY
SnAg	221 - 226	Automotive	Visteon (Ford)
SnAgBi	206 - 213	Military/Aerospace	Panasonic
		Consumer	Hitachi
SnAgBiCu		Military/Aerospace	Panasonic (FA Controller?)
SnAgBiCuGe		Consumer	Sony
SnAgBiX	206 - 213	Consumer	Panasonic
SnAgCu	217	Automotive	Panasonic
		Telecommunications	Nokia
			Nortel
			Panasonic
			Toshiba
SnBi	138	Consumer	Panasonic
SnCu	227	Consumer	Panasonic
		Telecommunications	Nortel
SnZn	198.5	Consumer	NEC
			Panasonic
			Toshiba

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Lead-Free Solder Selection

- **Fluxes**
  - Selection of lead-free alloy means changes in flux chemistries
  - Don’t plan on plugging current flux into new process
  - Will have to tweak chemistries for high-temperature soldering
  - Will need totally new flux if using SnZn
  - Changing flux chemistry affects cleaning processes, soldermask and coatings

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Lead-Free Components

- **Molded Components**
  - **Concerns with popcorning and delamination**
  - **Need time**
    - Qualification of new components
    - Definition of new materials
    - New molding compounds
  - **New compounds need to meet high-temp requirements**
  - **Compounds should meet WEEE halogen free requirements**
  - **J-STD-020 and J-STD-033 revisions in process**

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Lead-Free Components

- **Molded components**
  - **Manufacturing experiences and concerns of finishes**

Finish	Manufacturing Experience	Concerns
NiPd	Yes	Material cost (Process is cheaper; must switch 100%)
NiPdAu	Yes	Material cost
SnBi	No	The assembly must be totally Pb free.
Sn	Yes	Tin whiskers
SnCu	Yes	Tin whiskers

Lead-Free Components

- **Die attach**
  - **AuSi eutectic**
    - Not applicable to large die because it's brittle
    - Tends to crack large silicon dies
  - **AuSn eutectic**
    - Melts at 180
    - Definition of new materials
    - For new molding compounds
  - **New compounds need to meet high-temp requirements**
  - **Compounds should meet WEEE halogen free requirements**
  - **Organic can use Ag-filled epoxy**

Lead-Free Components

- **Flip chip/CSP**
  - **No known solution**
    - Internal to package
    - Temperature hierarchy
  - **Potential for use of patented Indium alloy or SnAgCu for direct chip**
  - **Some in industry may propose exemption for these parts**

Lead-Free Components

- **Connectors and through hole**
  - **Materials same as molded components**
  - **More data needed before making specific determinations**
- **BGA**
  - **Form balls with SnAgCu**
    - Need to pay attention to affects of high-temperature solder
    - Concerns with warpage of BGAs
  - **Very little data currently available, but being gathered by NEMI and others**

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PWBs

- **Organic Solderability Preservatives (OSPs)**
  - **Viable candidate**
    - Easily processable
    - Relatively free of ionic contaminants
    - Flatter than HASL
    - Good solderability
  - **Concerns**
    - Storage life
    - Need to handle with care
    - Durability with high melting temperatures
    - Need to assess flux chemistries used

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PWBs

- **Lead-Free Hot Air Solder Leveling (HASL)**
  - **Viable candidate**
    - Works well with most alternative solders
    - Wets faster than most plated finishes and coatings
  - **Concerns**
    - Warpage due to higher processing temperatures
    - PWB-absorbed process chemistries
    - Roundness of finish makes it hard to use with small leads
    - Safety issues with high-temperature solders
  - **Some manufacturers may move away from HASL altogether if required to go lead free**

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PWBs

- **Immersion Finishes (Precious Metals)**
  - **Viable candidate**
    - Surface flatness
    - Availability
    - Ease of process
  - **Concerns with thinness of coatings**
    - High soldering temperatures may result in out-diffusion of base metals and oxidation
    - Reduced solderability

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PWBs

- **Electroless NiAu**
  - **Viable candidate**
    - Resistant to damage during handling
    - Improved shelf life over other finishes
    - Free of ionic contaminants
    - Compatible with most flux chemistries
    - Flatter than HASL

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PWBs

- **Materials Considerations**
  - **Reliability in processing**
    - Warpage of PWB
    - Must be able to survive multiple reflows
    - High Tg doesn't necessarily mean laminate can survive high soldering temperatures
    - PTH reliability
    - High-temperature reflows also affect inks, adhesives and markings

Equipment

- **New Equipment Considerations**
  - **Solder pots**
  - **Reflow ovens**
  - **Concerns**
    - Cost of new equipment
    - Downtime for transition and training staff
    - Space limitations
  - **May not be necessary in all cases**

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When Given Lemons, Make Lemonade

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Roadblocks and Resolutions

- Lack of singularity of alloy
  - Industry needs to continue consortia efforts in down-selection of alloys
- Rework and repair impact
  - Need markings to indicate board is lead free
- Recycling requirements
  - Monitor state-level activities
  - Call upon consortia to make requirements
- Worker safety/exposure issues
  - Need data from EPA's DfE ASF project

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Roadblocks and Resolutions

- No definition for lead free
  - Call on IPC membership to take initiative
  - Possibly <0.1%?
- Lack of industry partnership
  - Continue efforts through consortia activities, such as roadmap development
- Need to know process requirements
  - Industry must share experiences
  - Go to suppliers for information
  - Industry-sponsored lead-free assembly training

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Roadblocks and Resolutions

- **Need to know process requirements**
  - Industry must share experiences
  - Go to suppliers for information
  - Industry-sponsored lead-free assembly training
- **Lack of reliability and long-term data**
  - Sharing of data
  - Consortia must team together
  - Accept or develop data for specific applications
  - Focus on what data is needed
  - Dissemination and acceptance of data

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Roadblocks and Resolutions

- **Toxicity/environmental impact of alternatives not clear**
  - **Need data from EPA**
  - **Care in selecting an alternative that won't face potential ban**
- **No government pressure in US to switch to lead free**
  - **To preclude an possible legislative activities, industry should take the initiative to research alternatives in anticipation of US legislation**

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Roadblocks and Resolutions

- **Slow pace of standards development**
  - **Rigorous streamlining of standards revision process**
  - **Standards revision must focus on lead-free as a priority**
  - **Intensify liaison work with international associations**
  - **Industry sectorization of standards and specifications (i.e., telecommunications, automotive)**

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The Path Ahead

- **IPC will remain active in lead free arena**
  - **Mustn't allow industry to forget again**
  - **Continue to provide information**
  - **Periodic roadmap updates**
- **Industry needs to be prepared**
  - **Legislation may hit US shores**
    - IPC **will not** oppose any legislation
  - **Japanese lead-free consumer electronics to be released in US - This year!**

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Do you want to be a market leader, or a market follower?

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